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The purpose of the ISS OSI Invited Meeting being held in Vienna March 24-27, 2009 is to obtain a better understanding of the phenomenology of underground nuclear explosions for On-Site Inspection (OSI) purposes. In order to focus the technology discussions, we have developed two very general scenarios, or models, of underground nuclear test configurations and phenomena that will help us explore the application of OSI methodologies and techniques. The scenarios describe testing environments, operations, logistics, equipment, and facilities that might be used in conducting an underground nuclear test. One scenario involves emplacement of a nuclear device into a vertical borehole in an area with relatively flat terrain; the other involves emplacement within a tunnel (horizontally) in an area with mountainous terrain.

Vertical borehole geometry

The example for this scenario is an intermediate yield nuclear explosion carried out in a flat desert area. The ground was cleared and smoothed over a 200 X 200 m fenced area for operational support activities, access to the borehole, and in order to place a few structures to house diagnostics equipment and control functions. Power lines were provided for local electrical power. The vertical emplacement borehole was 2 m in diameter and bored to a depth of 350 m. The emplacement hole was lined with steel pipe in order to keep the hole open and to avoid cave-ins during emplacement of the nuclear device. Emplacement was above the local water table, and the top of the saturation zone is about 30 m below the bottom of the emplacement hole. The detonation point was at a depth of 340 m. All of the rock material removed while drilling the borehole was removed to another place. Diagnostics and control for the test were relatively simple: about 2 dozen high capacity coaxial cables feed from the down hole instruments to the surface and then about 100 m laterally to a diagnostics trailer. Two strong steel cables were used to emplace the device and diagnostic instruments and to support the down hole cables. The borehole was stemmed after the device was emplaced. The stemming material was relatively simple: the hole was backfilled with sand or gravel about 20 – 30 m above the nuclear experiment package, a grouted plug about 3 m thick is added, and the hole backfilled with a mixture of sand and gravel to the surface. After the test, the testing party removed all structures and power lines and covered the top of the borehole with a small building.

Geologic environment before the test -- The geology for the test consists of flat-lying alluvium and tuff, with 50 m of poorly consolidated alluvium near the surface and moderately welded tuff from 50 m depth to 50 m below the bottom of the hole. The upper tuff is underlain by a densely welded tuff unit, with basement Paleozoic sedimentary rock beginning at a depth of about 1000 m. The tuff is intact with a few fractures. There are no known faults located within 500 m of the borehole.

Alteration of the underground environment – The blast created a spherical or near spherical cavity with a lens of vitrified material at the bottom. There are several zones surrounding the detonation point with decreasing levels of rock damage. The zones are: 1) the crushed zone (several tens of meters)where the rock has lost all prior integrity; 2) the fractured zone (out to a couple of hundred meters)characterized by radial and concentric fissures; and (3) the zone of irreversible strain (out to a couple of thousand meters) with local media deformation. A collapse chimney formed one hour after the detonation, in which overlying material fell into the explosion cavity. This chimney zone reached up to within 50 m of the surface and a small apical void formed (10 m high and 80 m in diameter) at the top of the rubble chimney. The rubble chimney is dry and density is about 20% less than the surrounding intact rock.

Alteration at the surface – No surface depression formed, but there is significant "fluffing" of the surface soil from the effects of the initial shock wave. A few radial and concentric fractures formed from the shock effects within a radius of 200 m of the borehole.

Radionuclide environment – No particulates or aerosol radiological material reached the surface. However, the stemming is not completely impervious to gas release and a small amount of gas and vapor was released along the emplacement pipe immediately after the explosion and before the rubble chimney formed. Most of the gas venting stopped as soon as cavity collapse occurred. After the rubble chimney formed and the pressure in the explosion cavity reached equilibrium, gases began to migrate up through the rubble chimney aided by barometric pumping. There is also an unknown fault located 300 m from the explosion cavity that provided another gas migration pathway between the damage zone of the cavity and the surface. Venting of radioactive gas through the fault to the surface began shortly after the detonation and stopped with cavity collapse.

Tunnel geometry

In this scenario a low yield device was detonated in hard rock (granite) in a sparsely wooded, mountainous area. The explosive device is emplaced in a 5 m by 5 m by 3 m alcove at the end of a 3 m by 3 m, 500 m long tunnel with a mine rail system. The tunnel was mined in a due north direction. There are no side drifts and only a few equipment side alcoves (~1 m depth). Tunnel supports (rock bolts, screening) were needed in only a few sections leaving most of the rock walls exposed and generally observable. There is ventilation pipe hanging from the back (ceiling) in to the first containment plug. The emplacement alcove is located 400 m beneath the nearest free surface. The terrain above the emplacement point is rugged and difficult to access and traverse. A well-maintained road leads to the fenced portal area of the mining tunnel and there are power lines and several buildings (which look like typical mine support facilities) located outside. Diagnostics and control for the test were accomplished via about 20 high capacity coaxial cables run to the alcove in a protective cable tray attached to the rib (side) of the tunnel 1.2 m above the invert (floor). Five meter-thick concrete barriers between steel walls were constructed in the tunnel at distances of 50 m and 100 m from the alcove, otherwise the tunnel is open out to the portal doors. No special preparations were carried out to seal the cables and power lines, nor the cable tray.

Geologic environment of the test -- The geology consists of granite gneiss with a regional crude layering that has a dip to the north of about 30° from the horizontal. There are no known major faults or other discontinuities in the area, but there are well defined weaker zones, with spacing about 10 m, that follow the layering observed in the main tunnel.

Disruption of the underground environment – Blast effects around the detonation point are less extensive than for the borehole scenario, because of the hard rock geology and lower yield of the device. The crush zone extends to a few tens of meters radius from the detonation point, the fractured zone out to several tens of meters, and the zone of irreversible strain extends to the portal of the tunnel. Because of the hard rock, there is limited cavity collapse and the rubble chimney extends upward only a few cavity radii. Because of the presence of carbonate material in the rock, there are significant noncondensible gases formed by the explosion that maintain elevated pressure behind the first containment barrier for several days. The first containment barrier is not significantly damaged. There is observable damage to rail tracks, cable troughs, and other infrastructure in the tunnel out to distances within 150 m of the tunnel entrance due to shock effects. The explosion pressure in the cavity pushed gas and vapor out through several fractures and bedding planes to beyond the crush zone and several tens of meters into the fractured zone.

Ground disruption at the surface – Surface effects are minimal, due to the depth of the detonation point from the surface (400 m). However, there are a few minor rock falls, disturbed rocks, and minor landslides that occur along steep slopes within 500 m radius of surface ground zero. Some of the larger trees on the steeper slopes show disturbed soil around their trunks. There is no evidence of damage from shock waves at the entrance of the tunnel.

Radionuclide environment – Because of the pressurization from the cavity after the explosion, venting occurs around the edges of the first containment barrier, allowing radioactive gas to enter the tunnel between the two containment barriers. Gas does not vent beyond the outer containment barrier. Radioactive gas is also forced into extension fractures several tens of meters out from the detonation point and some of this gas enters a pre-existing joint system that eventually intersects with the surface. These gases move toward the surface over the next several months aided by barometric pumping. No radioactive signatures exist at the tunnel portal.